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## **Ecosystem paramter mapping in Swiss National Park based on a continuous fields approach**

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**Abstract:** Adequate assessment and management of landscape patterns and processes need proper representation and quantification of gradients of ecosystem biochemical and structural properties. Discrete land cover mapping approaches represent landscapes as classified entities with “hard” boundaries. On the other hand, continuous field representations of land cover or ecosystem parameters offer the potential to overcome the limitations of classified entities that can often not reproduce the full range and variability of land surface properties. This paper presents a concept to generate continuous fields (CF) maps of ecosystem parameters in an alpine environment. The concept is exemplarily presented on a high mountain ecosystem’s total (above ground) water content and is performed in the upper Trupchun valley (Val Trupchun) in the Swiss National Park (SNP). It is applicable to further parameters. Airborne Prism EXperiment (APEX) imaging spectrometer (IS) data collected over the SNP in June 2010 and 2011 are used for CF mapping of water content. Abundance maps of predominant land cover classes are derived from linear spectral mixture analysis (SMA). They are then combined with individual thematic water content information of the respective land cover originating from either spectral indices or a physically based approach. The resulting product depicts a spatially continuous representation of total water content. The availability of APEX IS data from two consecutive seasons allows studying differences in ecosystem water content over time. CF maps can be generated for a wide range of ecosystem parameters. If multi-temporally available, such products can be useful for explaining ecological patterns such as animal grazing patterns in SNP.

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# ECOSYSTEM PARAMETER MAPPING IN SWISS NATIONAL PARK BASED ON A CONTINUOUS FIELDS APPROACH

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## ABSTRACT

Adequate assessment and management of landscape patterns and processes need proper representation and quantification of gradients of ecosystem biochemical and structural properties. Discrete land cover mapping approaches represent landscapes as classified entities with “hard” boundaries. On the other hand, continuous field representations of land cover or ecosystem parameters offer the potential to overcome the limitations of classified entities that can often not reproduce the full range and variability of land surface properties.

This paper presents a concept to generate continuous fields (CF) maps of ecosystem parameters in an alpine environment. The concept is exemplarily presented on a high mountain ecosystem’s total (above ground) water content and is performed in the upper Trupchun valley (Val Trupchun) in the Swiss National Park (SNP). It is applicable to further parameters. Airborne Prism EXperiment (APEX) imaging spectrometer (IS) data collected over the SNP in June 2010 and 2011 are used for CF mapping of water content. Abundance maps of predominant land cover classes are derived from linear spectral mixture analysis (SMA). They are then combined with individual thematic water content information of the respective land cover originating from either spectral indices or a physically based approach. The resulting product depicts a spatially continuous representation of total water content. The availability of APEX IS data from two consecutive seasons allows studying differences in ecosystem water content over time. CF maps can be generated for a wide range of ecosystem parameters. If multi-temporally available, such products can be useful for explaining ecological patterns such as animal grazing patterns in SNP.

**Index Terms**— APEX, Swiss National Park, alpine ecosystem, continuous fields mapping, water content

## 1. INTRODUCTION

The representation of gradients of biochemical and structural properties of ecosystems using a continuous fields (CF) approach bears advantages in comparison to discrete land cover classification schemes. Mapping land surface properties as gradients with gradual differences is today considered a more realistic approach than using discrete classes with hard boundaries. Since discrete land cover mapping represents landscapes as a spatial mosaic of classified entities [1][2], such classes can not reproduce the full range and variability of land surface properties that often are necessary to adequately quantify and manage landscape patterns and processes [2][3]. As a consequence, the concept of CF offers a solution to represent gradients of biochemical and structural properties of ecosystems, rather than classified entities of such properties. The suite of MODIS vegetation continuous fields (VCF) is an example of globally produced annual land cover products at 500 m sub-pixel resolution [4].

## 2. METHODS AND DATA

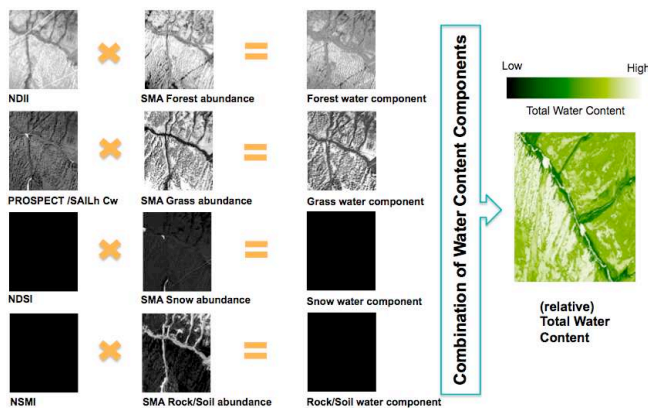
### 2.1. Generation of Continuous Fields (CF) Maps

The derivation of land surface properties from remote sensing data for ecological studies can provide information about ecosystem conditions and habitat status. This contribution describes the generation of CF maps of biogeochemical and –physical ecosystem parameters (e.g., *total water content*, *total above ground biomass* or ecosystem *Gross Primary Production* (GPP)) in a high mountain environment, namely the Swiss National Park (SNP). The study’s main emphasis is on demonstrating the potential of using remote sensing derived continuous information in ecosystem studies, rather than fundamentally improving the accuracy of parameter retrieval itself. We demonstrate the generation of CF maps of ecosystem parameters on the specific example of total (above ground)

water content (Cw). The presented approach consists of two main steps (Figure 1):

- First, spectral mixture analysis (SMA) derived abundance maps of predominant land cover types (i.e., forest, grassland, snow and rock/soil) are generated.
- Second, these abundance maps are combined with individual thematic information (either based on empirical (e.g. spectral indices) or physical modeling) of each land cover type, resulting in a spatially continuous product.

In the case of forest stands, water content is related to the *Normalized Difference Infrared Index* (NDII) [5]. For grassland, water content estimates are based on the inversion of a *1-D radiative transfer* (RT) model (PROSPECT [6]-SAILh [7] model) combination. For snow covered areas, the *Normalized Difference Snow Index* (NDSI) [8] is used, assuming high NDSI values to correspond to high snow cover and thus to contain high water content. The *Normalized Soil Moisture Index* (NSMI) [9] is applied to estimate water content in soil (and potentially on rocks). Due to lacking ground truth of land cover type specific water content, our final water content map represents *relative* values of total water content.



**Figure 1.** Schematic outline of CF maps generation of biogeochemical and –physical ecosystem parameters. The detailed description is given for (relative) total water content.

## 2.2. Study Area and Data

### 2.2.1. Swiss National Park (SNP)

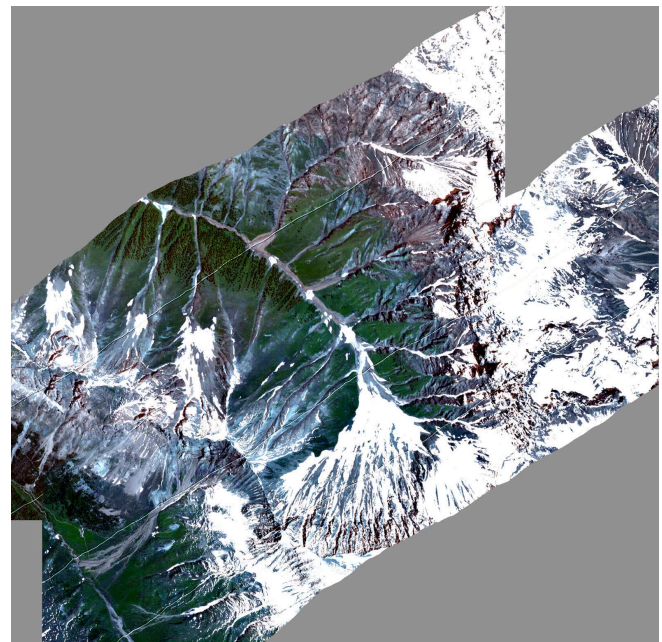
The study area is located in the upper valley of Trupchun (Val Trupchun) in the Swiss National Park (SNP). The SNP covers an area of 172 km<sup>2</sup> in the south-eastern part of Switzerland with elevations ranging from 1350 to 3170 m above seal level. Predominant land cover is composed of alpine grassland communities distributed over a large altitudinal range (1800-2600 m asl.), rocks and bare soil, snow fields depending on the season and open forest stands

of Swiss stone pine and larch (*Pinus cembra*, L. / *Larix decidua*, Mill.) up to about 2150 m asl. The climate of the area is alpine and the growing season starts late. Average annual precipitation is ca. 700 mm.

### 2.2.2. APEX Imaging Spectrometer Data

Airborne Prism EXperiment (APEX) imaging spectrometer (IS) data [10][11] of the area were acquired in two consecutive years on June 24, 2010 and June 26, 2011, respectively. IS data acquisition over the SNP is performed in close collaboration with the park authorities on a recurring basis to assess ecosystem processes over time.

The IS data were geometrically and atmospherically corrected using PARGE [12] and ATCOR-4 [13] standard approaches and consequently mosaicked (Figure 2). An evaluation of the orthorectified data showed that the geometric distortions are less than one pixel (2m) in comparison to ground-based GPS measurements.

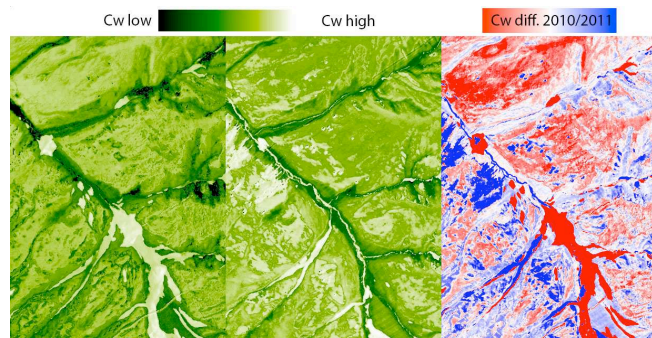


**Figure 2.** True colour composite of a mosaicked APEX imaging spectrometer scene of upper Trupchun valley acquired on June 24, 2010.

## 3. RESULTS AND DISCUSSION

Figure 3 shows a subset of the CF maps of relative total water content in Val Trupchun for June 24, 2010 (left) and June 26, 2011 (middle). A difference map showing the percentage difference in total water content between the two CF maps is given in Figure 3 (right). The blueish and reddish colours represent the two dates' subtle differences in water content of less than 5%. Dark blue and dark red represent differences >5%. In general, large negative

differences (red) between the two consecutive years can mainly be found at high altitudes (snow cover, not shown here), whereas large positive differences (blue) are predominantly present below the tree line.



**Figure 3.** Subset of CF map of (relative) total water content (Cw) of June 24, 2010 (left), June 26, 2011 (middle) and difference map [%] (right). Blueish and reddish colours show differences of less than 5% in the two dates' total water content. Dark blue and dark red depict differences >5%.

CF maps of ecosystem parameters bear the potential to spatially and temporally represent small-scale variations and gradients that could otherwise not be assessed when using discrete classes of land surface properties. The proposed methodology reveals differences in the two water content products, although the IS data collection took place on almost identical days of the year (DOY, i.e., June 24, 2010 and June 26, 2011). Besides considerably less snow present in the high altitudes of the study area in June 2011 compared to June 2010, inter-annual phenological differences in tree/vegetation development can be identified. This is mainly the case for the predominant larch (*Larix decidua*, Mill.). The analysis of meteorological data from a nearby weather station contains indications of an advanced phenology in 2011 (e.g., temperature, sunshine duration, precipitation). The first growing degree day with temperatures above 5°C (GDD<sub>5</sub>) was reached 17 days earlier in 2011 compared to 2010.

#### 4. CONCLUSION

The concept of using CF to represent ecosystem parameters and their gradients overcomes limitations traditionally introduced to data analysis and model parameterization when using discrete classes of land surface properties. Imaging spectrometer data from consecutive seasons allow for the study of stable patterns or variations of ecosystem parameters (e.g., *total water content*, *total above ground biomass*) in the observed area over time. Such CF maps as the presented total water content map of a high alpine environment, i.e., the Swiss National Park, will be used by park authorities and ecologists to help understand animal

distribution and habitat use. For instance, the availability of water in alpine grasslands is, among others, an important factor for animal forage quality and quantity. Eventually, we plan to link CF maps of ecosystem parameters related to the water cycle, carbon (biomass, GPP) or nutrient cycles (N, Ca, fibres, etc.) to observations of spatial distributions and grazing patterns of ungulates in the park.

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